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XIII.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XXIV.—EXPERIMENTS WITH THE THERMAL
TELEPHONE.

BY CHARLES R. CROSS.

Communicated October 14, 1885.

In the *Telegraphic Journal* for 1880, p. 204, Mr. William H. Preece describes some very interesting experiments with a new form of telephonic receiver, consisting of a fine stretched wire, one end of which is attached to the middle of a diaphragm and the other to an adjustable support. The wire is placed in circuit with a voltaic battery and a microphone. When the microphone is actuated by the voice, the electrical undulations thereby produced in the battery circuit cause corresponding variations in the temperature, and hence in the tension of the wire, and thus the diaphragm is set into vibration, so that speech is reproduced.

Mr. Preece used six "bichromate of potash" cells. He does not state the amount of the heating effect on the wire, but from what is said it is evident that the temperature of the wire was but slightly elevated.

The statement of results in the paper referred to is quite brief; and the experiments detailed below were undertaken in order to ascertain to what extent speech can be reproduced by such a receiver, both as to loudness and intensity; to study somewhat further the changes due to variation in the length and diameter of wire of different materials, under varying conditions of current strength; and, especially, to observe the effect of varying the temperature of the wire. Most of the experimental work has been carried on, under my direction, by Messrs. W. J. Hopkins and J. O. Ellinger, students in the Laboratory of the Institute.

We first sought to find under what conditions we could realize the maximum loudness of speech using platinum wire, which had given

the best results with Mr. Preece. For a transmitter we used a Hunning microphone, a form of transmitter in which granulated carbon is employed, the powder being loosely confined between two metallic plates. The battery used consisted of from one to twelve Grenet cells, the maximum current used being sufficient to raise the temperature of a platinum wire, .01 in. in diameter and about 10 inches long, to redness. In order to avoid excessive heating of the transmitter it was placed in derived circuit with the battery and receiver. In some experiments the diaphragm was made of firm cardboard and in others of sheet-iron.

One would naturally suppose that the longer the wire, the greater would be the variations in tension, and hence the greater the loudness of the resulting sound. If, however, the length of the wire is increased beyond a certain limit, the quality of the articulation appears to become very inferior, even though the loudness may be somewhat increased; and the wire tends to assume a free vibration of its own, producing a confusing after-tone.

The heaviest wire that we used was 0.0095 in. in diameter, as want of the requisite current at the time of the experiments prevented our increasing the diameter beyond this. With it a length of about six inches gave in general the maximum loudness, as Mr. Preece had previously observed.

Using a platinum wire .004 in. in diameter and from six to seven inches long, with sufficient current to raise its temperature to dull redness, very remarkable results were obtained. Not only could the most unfamiliar conversation be understood, but words spoken into the transmitter were heard and understood with the ear at a distance of from two to ten inches from the diaphragm of the receiver, the character and loudness of the sound being very similar to that obtained when a Hunning transmitter is used with an ordinary magneto receiver. Using a somewhat shorter wire at the same temperature gave a decidedly better quality of sound, but the loudness was very materially diminished. Lowering the temperature caused a rapid diminution in the loudness of the sound.

Almost as good results were obtained with German-silver wire, a material not mentioned by Mr. Preece; but with this the influence of temperature was far less marked than in the case of platinum. In fact, quite as good results both as to loudness and distinctness of articulation were obtained when the wire was simply warm to the touch as when it was hotter. In this respect German silver differs from any of the other materials that we used. With iron and copper but few experiments were tried, and the results were quite unsatisfactory.

It is difficult to give any numerical estimate of loudness and distinctness in such experiments as these. The following tables, however, besides furnishing a more precise idea of our results, will show the result reached in some attempt to form a numerical estimate of the relative intensity under different circumstances. The loudness of an ordinary magneto receiver when used with a magneto transmitter, spoken into with a moderately loud tone of voice, is called 10.

German-Silver Wire, Diameter .007 in., just below Redness.

| Length. | Nature of Articulation. | Comparative Loudness. |
|------------------|-------------------------------------|-----------------------|
| 10½ inches . . . | Faint, but distinct | 3 |
| 7½ " . . . | Clearer | 7 |
| 5 " . . . | Same as in last experiment. | 8 |
| 3 " . . . | Poor and indistinct | 4 |

Platinum Wire, Diameter .0095 in., at Red Heat.

| | | |
|------------------|---------------------------------|---|
| 10½ inches . . . | No sound | 0 |
| 7½ " . . . | Very faint. | 1 |
| 5 " . . . | Quite distinct speech | 4 |
| 3½ " . . . | No sound | 0 |

Platinum Wire, Diameter .006 in., just below Redness.

| | | |
|----------------|------------------------------------|------------------|
| 10½ inches . . | Distinct | Fairly loud. |
| 7½ " . . | No change in distinctness. | Loud as magneto. |
| 6½ " . . | " " " | Louder. |
| 4½ " . . | " " " | Much fainter. |
| 2½ " . . | Very indistinct | Barely audible. |

In the last experiment the wire was cool when the shorter length was used.

Platinum Wire, Diameter .005 in., just below Redness.

| | | |
|--------------|------------------------------|------------------|
| 7 inches . . | Speech easily understood . . | Moderately loud. |
| 5 " . . | Clearer | " " |
| 3 " . . | Fairly distinct | Fainter. |

Platinum Wire, Diameter .004 in., just below Redness.

| | | |
|----------------|----------------------------|--------------|
| 10¾ inches . . | Speech fairly distinct . . | Faint. |
| 7½ " . . | Very distinct | Much louder. |
| 8½ " . . | Clear | Less loud. |
| 2½ " . . | " | " |
| 1½ " . . | No sound | Inaudible. |

Platinum Wire, Diameter .002 in., just below Redness.

| | | |
|--------------|---------------------------|---|
| 5 inches . . | Fairly distinct | 5 |
| 3 " . . | Less distinct | 9 |
| 1¾ " . . | No sound | 0 |

From these and other experiments, it appears that our best results were obtained with the wire of .006 in. and .004 in. in diameter, there being but little difference between them. The largest wire used (.0095 in. diameter) gave very poor results; and with the battery power used by us the finest wire employed (.002 in. diameter) was equally inefficient. Mr. Preece's best results were secured with platinum wire .001 in. in diameter. Also with the finer wire the most effective length was less than with the larger sizes. The most interesting point, however, developed in the course of our experiments is the effect of increasing the temperature, notably with platinum wire, in increasing the loudness of articulation of the thermal receiver. This will naturally be attributed to the greater expansibility of the wire at high temperatures. It is possible that with German silver the effect, good at moderate temperatures, is not bettered on heating the wire, because of a marked influence of temperature in diminishing its elasticity.

The question also suggested itself as to what effect, if any, would be produced if the microphone were placed in the primary circuit of an induction coil, and the wire receiver in the secondary circuit, so that the receiver would only be acted upon by the induced currents from the coil. Since the heating effect varies as the square of the current, with such an arrangement difference of sign in the current could not be perceived at the receiver, and therefore one would not expect to be able to distinguish articulate speech. We thought that, if any sound was produced, it would be interesting to study its quality as compared with the quality of the sound actuating the transmitter. Our results, however, were negative. A sound was produced on breaking the circuit, but no audible effect was observed on speaking or shouting into the transmitter. In these experiments German-silver wire was used, in the hope that even at ordinary temperatures it might prove sensitive. Independent heating by a current of hot air was tried, but without success.

An attempt was also made to use the thermal telephone as a transmitter. Sir William Thomson has shown, in his researches on the electro-dynamic qualities of metals (*Math. and Physical Papers*, Vol. II. p. 208), that the electrical resistance of wires is varied by their tension, and indeed it was in following out this idea that Professor Hughes was led to his invention of the microphone (*Telegraphic Journal*, May 15, 1878).

Slight as the variation in resistance must necessarily be with such a transmitter, we yet hoped that the exceeding sensitiveness of the magneto receiver would suffice to detect it. Our results, while not at all

striking, were sufficiently encouraging to lead us to hope for greater ultimate success. The thermal telephone, with a platinum wire $4\frac{1}{2}$ in. long and 0.004 in. in diameter, and an iron diaphragm, was placed in circuit with a battery of 10 Grenet cells and an ordinary hand telephone receiver. The current was sufficient to heat the wire almost to redness. All the joints of the wire were soldered to prevent the possibility of microphonic action, which at first caused some annoyance, but which was readily recognizable by the scratching sound produced by it. With the joints thus soldered, and every precaution taken to avoid such microphonic disturbances, we succeeded in hearing and understanding at the receiver the word "Hallo!" and some brief familiar sentences. The sound was low, but distinct and clear, and in quality quite unlike the sound produced by microphonic action. There seems to be no doubt that electrical undulations were produced in the circuit by variations in the stress to which the heated wire was subjected. Similar results were obtained with a smaller number of cells, even down to one; but the sound was then exceedingly faint and scarcely audible. Speech was also transmitted by a thermal transmitter in which German-silver wire was substituted for the platinum. It may be that the more marked results on heating the wire to a higher temperature by the use of a stronger battery indicate that at such a temperature the electrical effect of changes in stress in varying the resistance of a wire is increased.

ROGERS LABORATORY OF PHYSICS.